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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 971

FATIGUE TESTS ON 1/8-INCH ALUMINUM ALLOY RIVETS

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INTRODUCTION

For a number of years the Aluminum Company of America has been investigating in the Aluminum Research Laboratories the fatigue characteristics of riveted joints in aluminum alloy sheet. Because of the general interest of aircraft manufacturers in these tests, the NACA published some of the results. Reference 1 presents fatigue data from tests of 17S-T and 53S-T specimens with rivets having diameters of 1/4 inch or more.

The purpose of the present report is to summarize all the results of fatigue tests that have been made to date in the Aluminum Research Laboratories of lap joints having 1/8-inch aluminum alloy rivets. The rivet materials used were 17S-T, Al7S-T, and 24S-T aluminum alloys, while the plate materials were 24S-T and alclad 24S-T.

APPARATUS AND TESTS

All the joints tested were lap joints in 24S-T or alclad 24S-T aluminum alloy sheet, 1 inch wide and containing one 17S-T, Al7S-T, or 24S-T rivet per joint. The total lap in each case was 1/2 inch, giving an edge distance in the direction of stressing equal to 1/4 inch or two times the nominal rivet diameter. Table I gives a descriptive list of the test specimens. All tests were made in a rotating-beam-type machine giving a complete reversal of load tending to shear the rivets.

Figures 1 and 2 show photographs of the fatigue testing machines used. The machine shown in figure 1 was designed and built at the Aluminum Research Laboratories in 1930 and is described in reference 2. This machine

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was intended originally for testing rotating beam specimens having a maximum diameter of 2 inches, but it has been provided with special fixtures (shown in fig. 3) for testing joints. The machines shown in figure 2 were designed and built at the Aluminum Research Laboratories in 1942 and are specifically intended for use in tests of joints using the fixtures shown in figure 4.

The procedure for testing joints is the same in each of the two machines. In each test, four joints are bolted to the fixtures and the assembly subjected to a uniform bending moment and rotated about the axis of the fixtures. This procedure subjects each individual joint to a complete reversal of load during each cycle. The machine shown in figure 1 operates at 1400 rpm and the machine shown in figure 2 at 1750 rpm. Each is equipped with a switch which automatically turns off the current to the machine when a specimen fails.

Usually only one of the four joints fails in fatigue and this then precipitates the failure of the other three joints. It is sometimes difficult to determine the location of initial failure, whether in the rivet or the sheet, because the joints are mutilated considerably by the time the rotating beam finally stops. Such cases are reported as a combination failure. Usually, however, the location of initial failure is definite.

SUMMARY OF RESULTS

Table I summarizes the test results of 1/8-inch diameter rivets, with information on alloy and type of rivet, sheet alloy and thickness, preparation of the rivet holes, and type of failure. The data have been plotted in figures 5 to 14.

Table II gives the fatigue strengths as indicated by the curves of figures 5 to 14, for certain numbers of cycles of stress. The joints are listed in the order of decreasing strengths under static loading.

The data presented in this report suggest the following comparisons, although in some cases the evidence is rather meager:

1. For 17S-T and Al7S-T rivets, the joints can be

divided into three groups according to strength, the strongest being those in dimpled sheet, the next strongest those with plain drilled holes, and finally those with machine countersunk holes. The only exception is item 9 with 0.040-inch-thick sheet machine countersunk 0.050 inch deep with rivets driven by NACA Method E of reference 3. Since the depth of countersink was greater than the thickness of the sheet, the shear area of the rivets in these joints was greater than that of the other joints, which accounts partially, at least, for their higher strength.

2. The effect of the depth of the countersink on the strength of the joint could not be definitely determined. When the manufactured head is countersunk, the joints with full-thickness machine countersink are not as strong as those in which the countersink is only three-fourths the thickness of the sheet. This probably results from the high stresses developed by the feather edge obtained with a full-depth countersink. When the driven head is countersunk (NACA method of driving), the joints with more-than-full-thickness machine countersink are stronger than those in which the countersink is only three-fourths of the thickness of the sheet. The additional shear area produced by the more-than-full-thickness countersink apparently offsets any detrimental effects of a feather edge at the rim of the hole.

3. The joints with 17S-T or Al7S-T rivets in dimpled 0.040-inch sheet failed by tensile fatigue fracture of the sheet. The 24S-T rivets of item 2 were driven in 0.064-inch sheet; consequently, the joints failed by shearing the rivets. As a rule, the joints with plain drilled holes failed by shearing the rivets; while in the case of those with machine-countersunk holes the type of failure could not be definitely determined.

4. A comparison of items 1 and 3 indicates that the fatigue strength of joints in 24S-T sheet is a little greater than that of similar joints in alclad 24S-T.

5. A comparison of item 3 with 4, and 5 with 7 indicates that in static tests and in fatigue tests of small numbers of cycles (high stresses) 17S-T rivets are stronger than Al7S-T rivets; whereas for large numbers of cycles (low stresses) the strengths are practically the same.

6. A comparison of items 8 and 10 indicates that, when the fatigue failures occur in the rivet, the thickness of the sheet, whether 0.051 inch or 0.064 inch, is relatively unimportant except in the fatigue tests at high stresses (low number of cycles). In this case the use of thicker sheet results in a stronger joint.

7. A comparison of items 2, 5, and 8 indicates that 24S-T rivets are stronger in fatigue than 17S-T and Al7S-T rivets.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., July 25, 1944.

REFERENCES

1. Templin, R. L.: Fatigue Properties of Light Metals and Alloys. Proc., A.S.T.M., vol. 33, pt. II, 1933.
2. Hartmann, E. C., Lyst, J. O., and Andrews, H. J.: Fatigue Tests of Riveted Joints - Progress Report of Tests of 17S-T and 53S-T Joints. NACA ARR 4115, 1944.
3. Lundquist, Eugene E., and Gottlieb, Robert: A Study of Tightness and Flushness of Machine-Countersunk Rivets for Aircraft. NACA RB, June 1942.

TABLE I

FATIGUE TEST RESULTS ON 1/8-IN. DIAMETER ALUMINUM ALLOY RIVETS. (All fatigue tests made on 1-in. wide lap joints in aluminum alloy sheet with one rivet per joint. Tests made under complete reversal of load. All static tests made on 1-in. wide lap joints in aluminum alloy sheet with two rivets per joint. Edge distance parallel to load 1/4 in.)

Item No.	Rivet Alloy	Types of Heads		Sheet Alloy	Nominal Sheet Thickness	Preparation of Holes	Maximum Load per Rivet, lb	No. of Cycles	Location of Initial Failure
		Manufactured	Driven						
1*	17S-T	Ctsk, 100°	Flat	24S-T	0.040	Dimpled, 100° ctsk	581	Static test	rivet sheet sheet sheet sheet sheet sheet No failure
							284	88 300	
							281	140 600	
							247	212 900	
							198	223 100	
							176	490 500	
							134	30 359 100	
							131	105 097 000	
2*	24S-T	Button	Flat	24S-T	0.064	Drilled	580	Static test	rivet rivet rivet rivet rivet rivet No failure
							189	1 500 100	
							172	732 300	
							150	7 390 900	
							133	8 135 200	
							127	3 229 800	
							112	97 579 500	
3*	17S-T	Ctsk, 100°	Flat	Alc.24S-T	0.040	Dimpled, 100° ctsk	572	Static test	rivet sheet sheet sheet sheet sheet sheet sheet
							240	90 600	
							159	407 200	
							124	1 575 900	
							117	1 624 000	
							102	7 704 800	
							97	30 044 400	
							92	23 956 500	
4*	Al7S-T	Ctsk, 100°	Flat	Alc.24S-T	0.040	Dimpled, 100° ctsk	516	Static test	rivet sheet sheet sheet sheet sheet No failure
							250	152 600	
							200	403 600	
							150	1 767 600	
							120	6 634 500	
							110	49 216 800	
							100	111 872 600	

* Tests made in fatigue testing machine shown in figure 2. Other tests made in fatigue testing machine shown in figure 1.

TABLE I (Cont'd.)

Item No.	Rivet Alloy	Types of Heads		Sheet Alloy	Nominal Sheet Thickness	Preparation of Holes	Maximum Load per Rivet, lb	No. of Cycles	Location of Initial Failure
		Manufactured	Driven						
5*	17S-T	Button	Flat	Alc.24S-T	0.040	Drilled	498	Static test	rivet sheet rivet combination combination sheet sheet combination combination combination No failure
							246	153 100	
							189	338 300	
							141	2 362 600	
							118	11 724 300	
							110	6 270 700	
							105	1 346 200	
							105	4 319 000	
							103	3 970 300	
							100	13 404 700	
							83	100 507 600	
7*	A17S-T	Brazier	Flat	Alc.24S-T	0.040	Drilled	445	Static test	rivet rivet rivet rivet rivet rivet rivet rivet rivet rivet rivet
							263	33 900	
							189	466 400	
							175	318 500	
							141	1 450 000	
							126	4 759 700	
							112	4 116 900	
							102	2 834 800	
							92	29 869 300	
							83	36 403 400	
							77	2 088 900	
8	A17S-T	Button	Flat	24S-T	0.064	Drilled	431	Static test	rivet rivet rivet rivet rivet No failure
							200	63 500	
							150	226 000	
							125	653 000	
							100	2 848 800	
							90	28 423 200	
9*	A17S-T	Button	Ctsk 60° N.A.C.A. Method of Driving	24S-T	0.040	Machine ctsk 0.050 in. deep	421	Static test	rivet rivet rivet rivet rivet rivet rivet rivet rivet No failure
							246	21 000	
							196	203 800	
							141	434 500	
							131	1 131 800	
							117	2 635 300	
							102	1 670 300	
							102	78 599 400	
							92	101 007 500	

* Tests made in fatigue testing machine shown in figure 2. Other tests made in fatigue testing machine shown in figure 1.

TABLE I (Concluded)

Item No.	Rivet Alloy	Types of Heads		Sheet Alloy	Nominal Sheet Thickness	Preparation of Holes	Maximum Load per Rivet, lb	No. of Cycles	Location of Initial Failure
		Manufactured	Driven						
10	Al7S-T	Button	Flat	24S-T	0.051	Drilled	416 200 150 125 125 100	Static test 100 173 100 109 000 788 900 21 555 700	rivet rivet rivet rivet rivet rivet
11	17S-T	Ctsk, 100°	Flat	Alc. 24S-T	0.040	Machine ctsk 100° (3/4 depth)	198 173 149 140* 125 111* 109 105* 100* 99	100 171 100 459 900 908 900 620 400 4 537 100 3 118 300 1 544 500 1 237 800 8 988 300	rivet sheet combination combination combination combination combination combination combination combination
12*	Al7S-T	Button	Ctsk 60° N.A.C.A. Method of Driving	24S-T	0.040	Machine ctsk 0.030 in. deep	386 239 214 196 179 141 132 116 97 92 87 84	Static test 2 000 59 000 103 700 88 500 57 800 665 900 875 700 12 952 300 6 939 000 97 742 400 1 196 600	rivet rivet rivet rivet rivet rivet rivet rivet rivet rivet rivet rivet
13	17S-T	Ctsk, 100°	Flat	Alc. 24S-T	0.040	Machine ctsk 100° (full depth)	185* 151* 148 125 125 99 92* 85* 75 65* 55	600 215 400 500 150 910 200 1 289 800 1 147 000 5 759 700 3 141 800 62 370 200 32 841 600	sheet combination rivet rivet sheet sheet combination combination - No failure No failure

* Tests made in fatigue testing machine shown in figure 2. Other tests made in fatigue testing machine shown in figure 1.

TABLE II

SUMMARY OF STATIC AND FATIGUE TEST RESULTS ON 1/8-IN. DIAMETER ALUMINUM ALLOY RIVETS. ALL FATIGUE TESTS MADE UNDER COMPLETE REVERSAL OF LOAD. EDGE DISTANCE PARALLEL TO LOAD 1/4 IN.

Item No.	Rivet Alloy	Type of Heads		Sheet Alloy	Nominal Sheet Thickness, in.	Preparation of Holes	Static Strength, lb/rivet	Fatigue Strength, lb/rivet		
		Manufactured	Driven					10 ⁵ cycles	10 ⁶ cycles	10 ⁷ cycles
1	17S-T	ctsk, 100°	flat	24S-T	0.040	dimpled, 100° ctsk drilled	581	250 S*	155 S	137 S
2	24S-T	button	flat	24S-T	0.064		580	255 R	185 R	155 R
3	17S-T	ctsk, 100°	flat	Alc.24S-T	0.040	dimpled, 100° ctsk	572	252 S	152 S	100 S
4	Al7S-T	ctsk, 100°	flat	Alc.24S-T	0.040	dimpled, 100° ctsk drilled	516	265 S	170 S	115 S
5	17S-T	button	flat	Alc.24S-T	0.040		498	260 C	150 C	104 C
7	Al7S-T	brazier	flat	Alc.24S-T	0.040	drilled	445	250 R	153 R	98 R
8	Al7S-T	button	flat	24S-T	0.064	drilled	451	178 R	118 R	92 R
9	Al7S-T	button	ctsk, 60°	24S-T	0.040	machine ctsk, 0.050" deep drilled	421	202 R	129 R	106 R
10	Al7S-T	button	flat	24S-T	0.051		416	142 R	125 R	107 R
11	17S-T	ctsk, 100°	flat	Alc.24S-T	0.040	machine ctsk, 5/4 depth	402	169 C	123 C	100 C
12	Al7S-T	button	ctsk, 60°	24S-T	0.040	machine ctsk, 0.050" deep	386	193 R	119 R	93 R
13	17S-T	ctsk, 100°	flat	Alc.24S-T	0.040	machine ctsk, full depth	379	158 R	102 S	60 C

* S indicates initial failure in the sheet, R in the rivet, and C a combination failure.

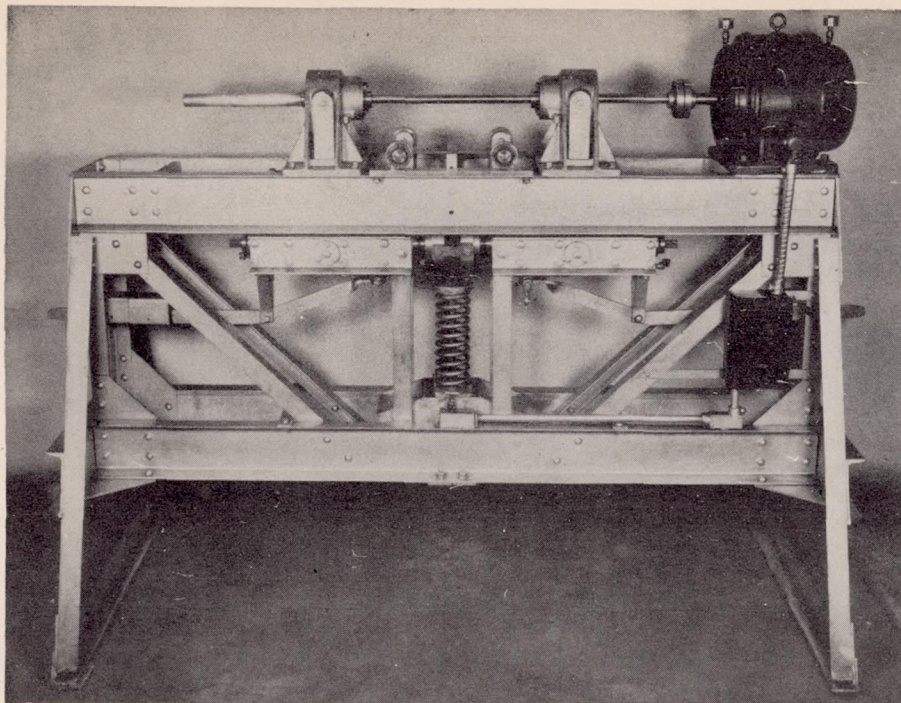
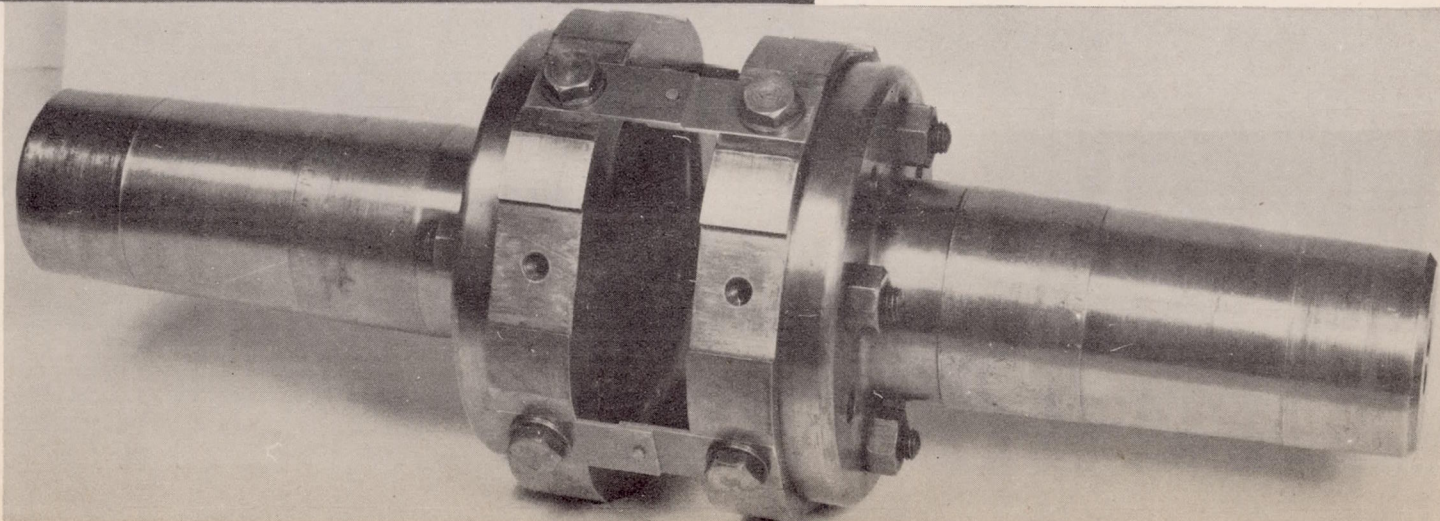


Figure 1.- Fatigue testing machine of rotating beam type designed and built at Aluminum Research Laboratories in 1930.



Figure 3.- Fixtures for loading riveted joints in fatigue testing machine shown in figure 1.



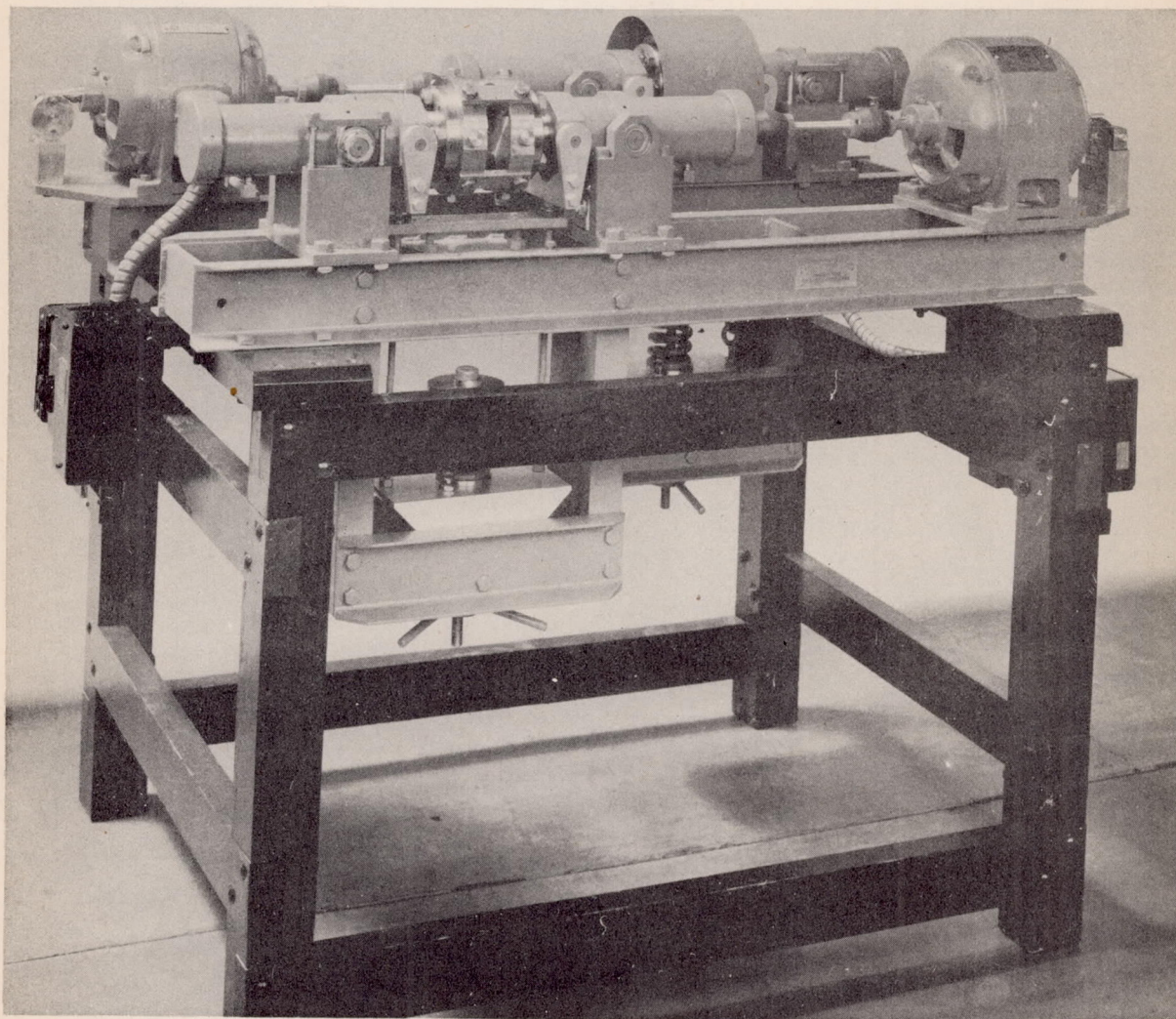


Figure 2.- Fatigue testing machines of rotating beam type designed and built at Aluminum Research Laboratories in 1942.

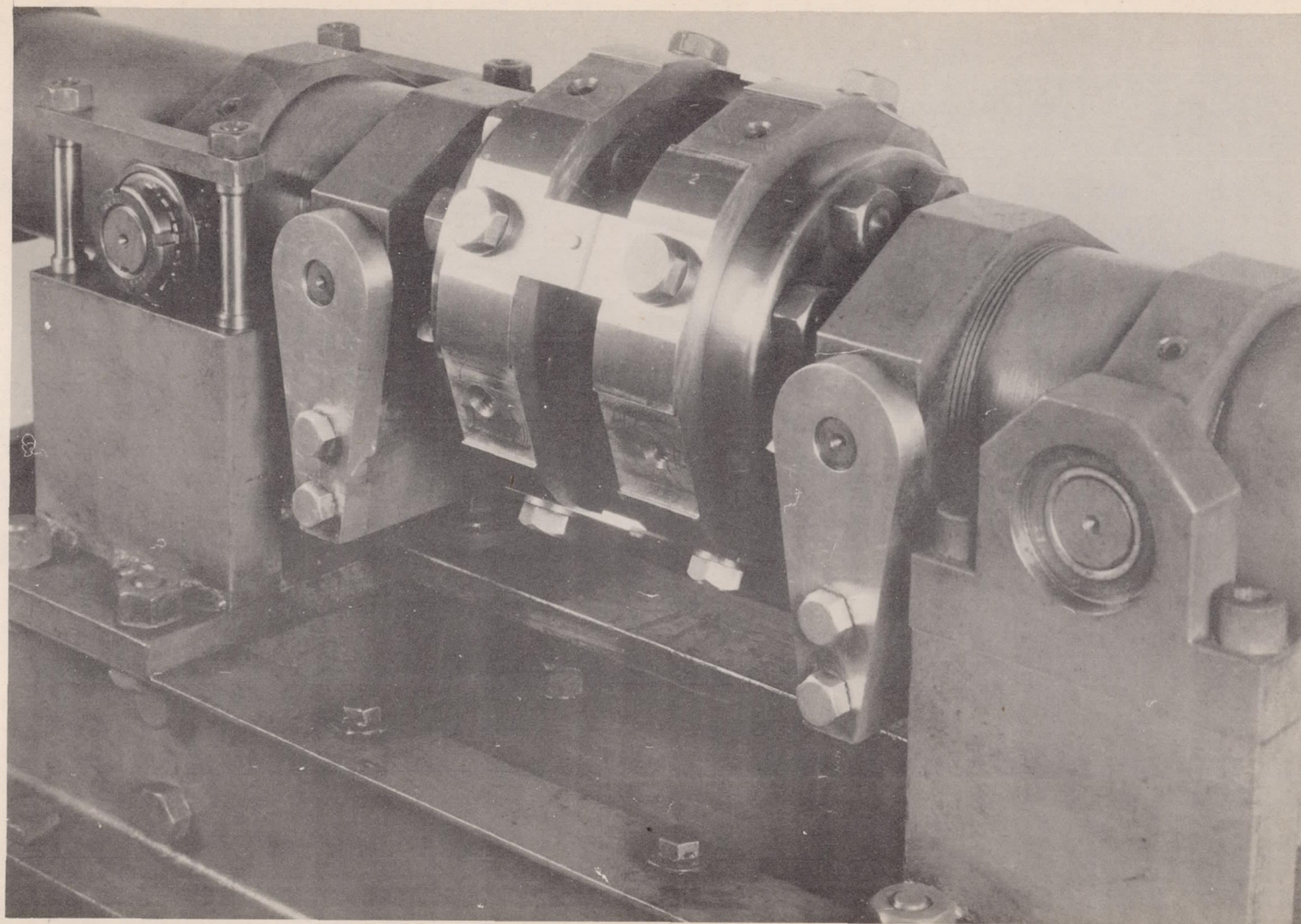


Figure 4.- Fixtures for loading riveted joints in fatigue testing machine shown in figure 2.

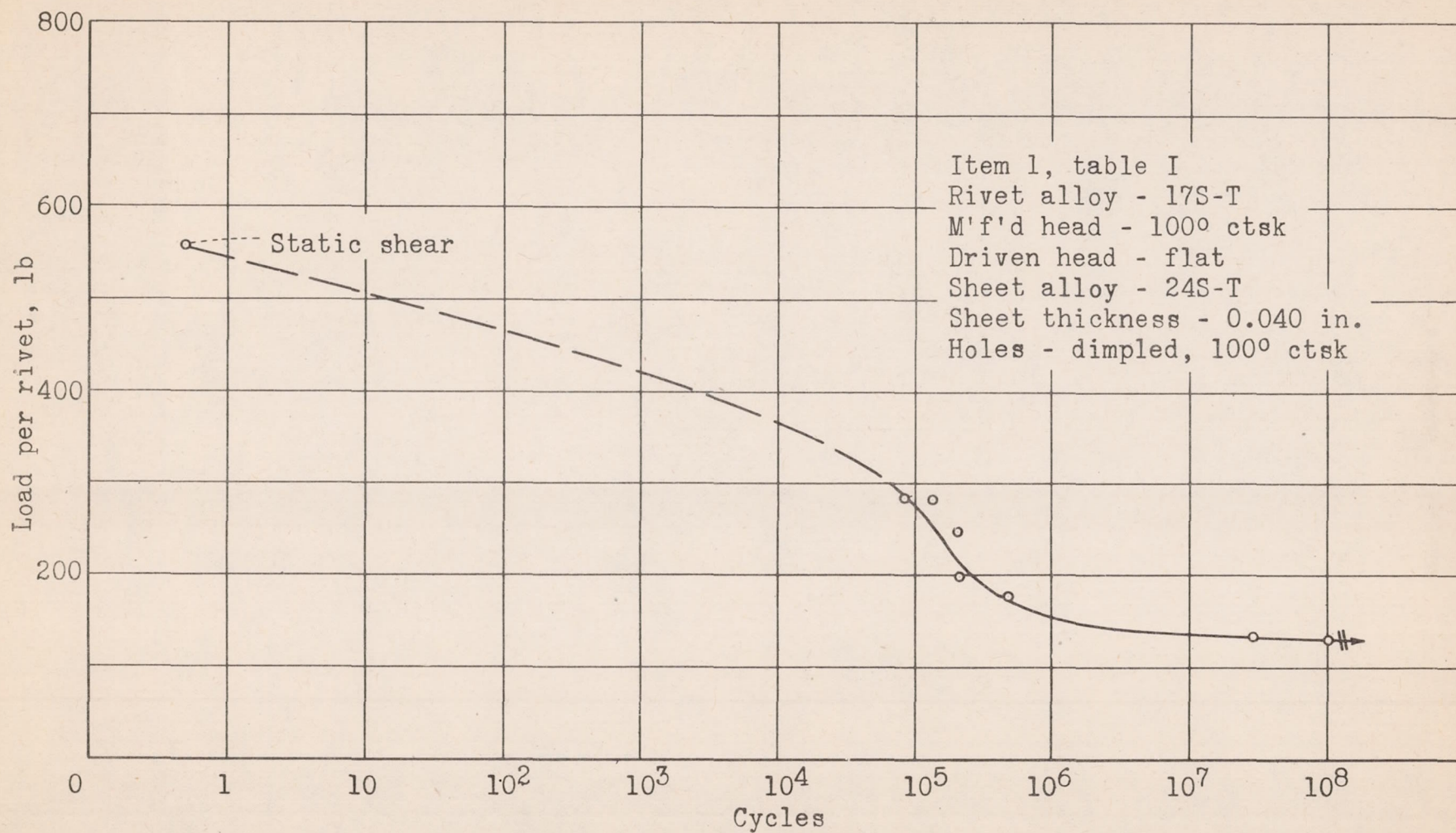


Figure 5.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

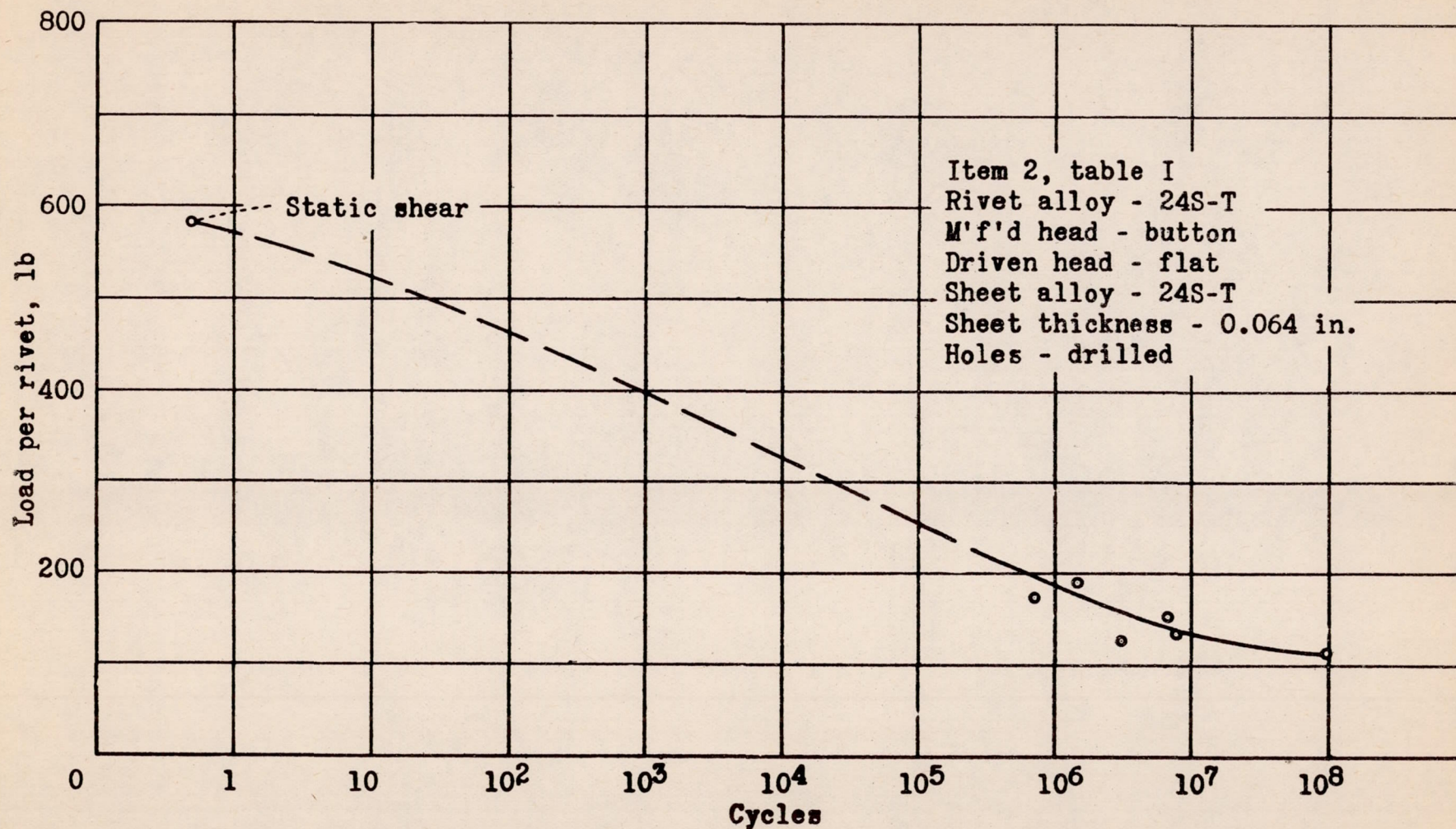


Figure 6.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

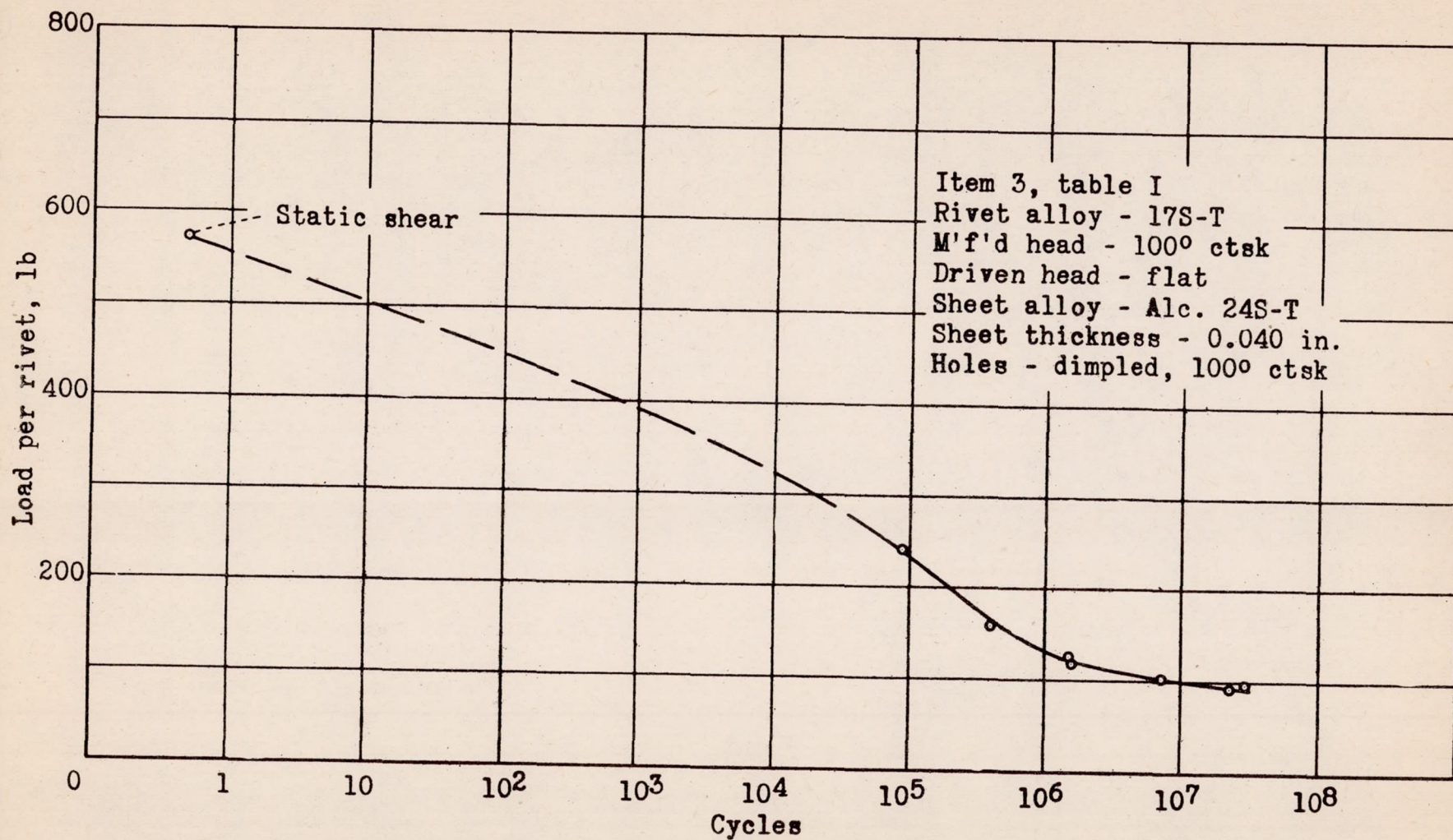


Figure 7.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

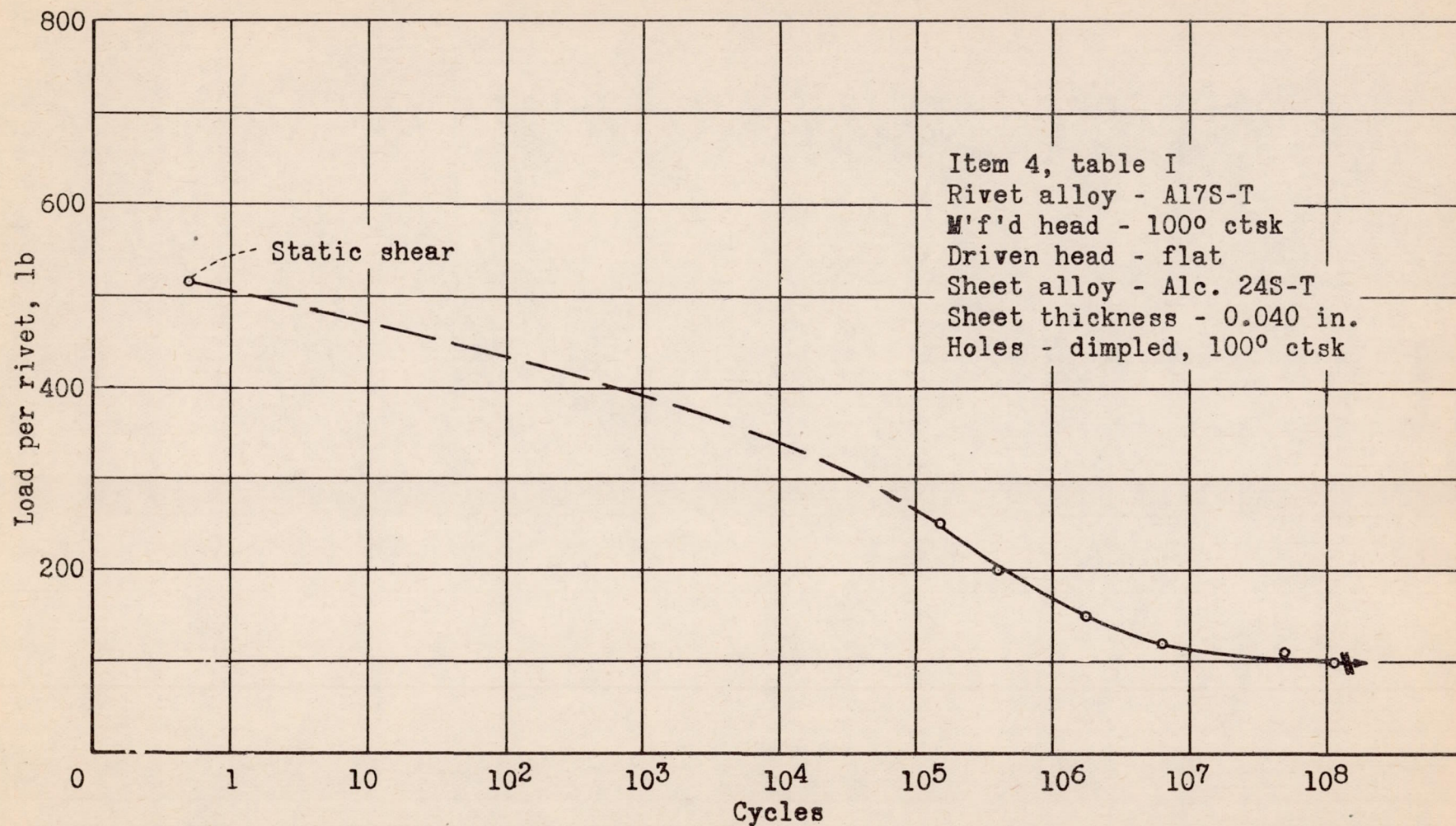


Figure 8.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

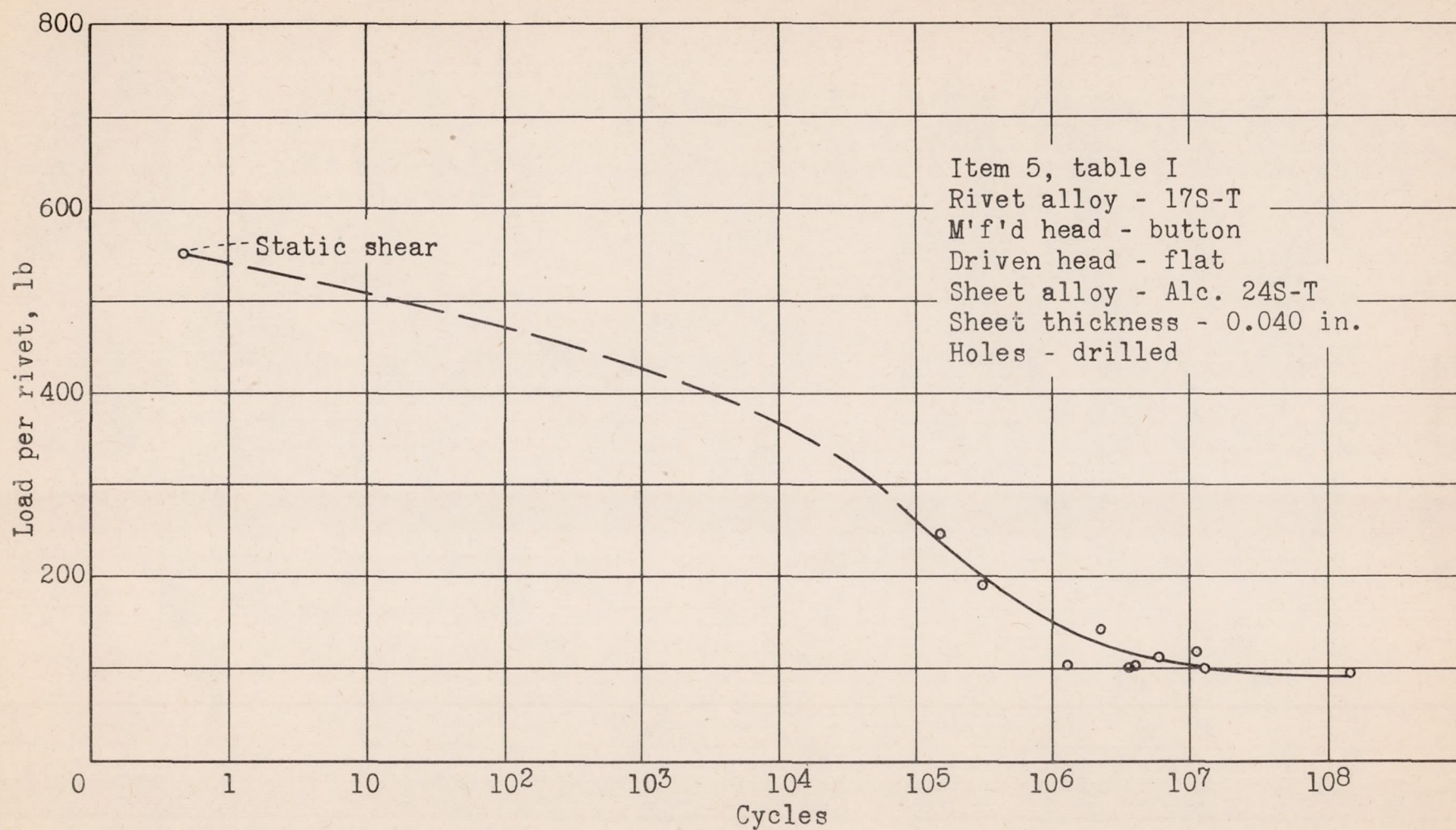


Figure 9.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

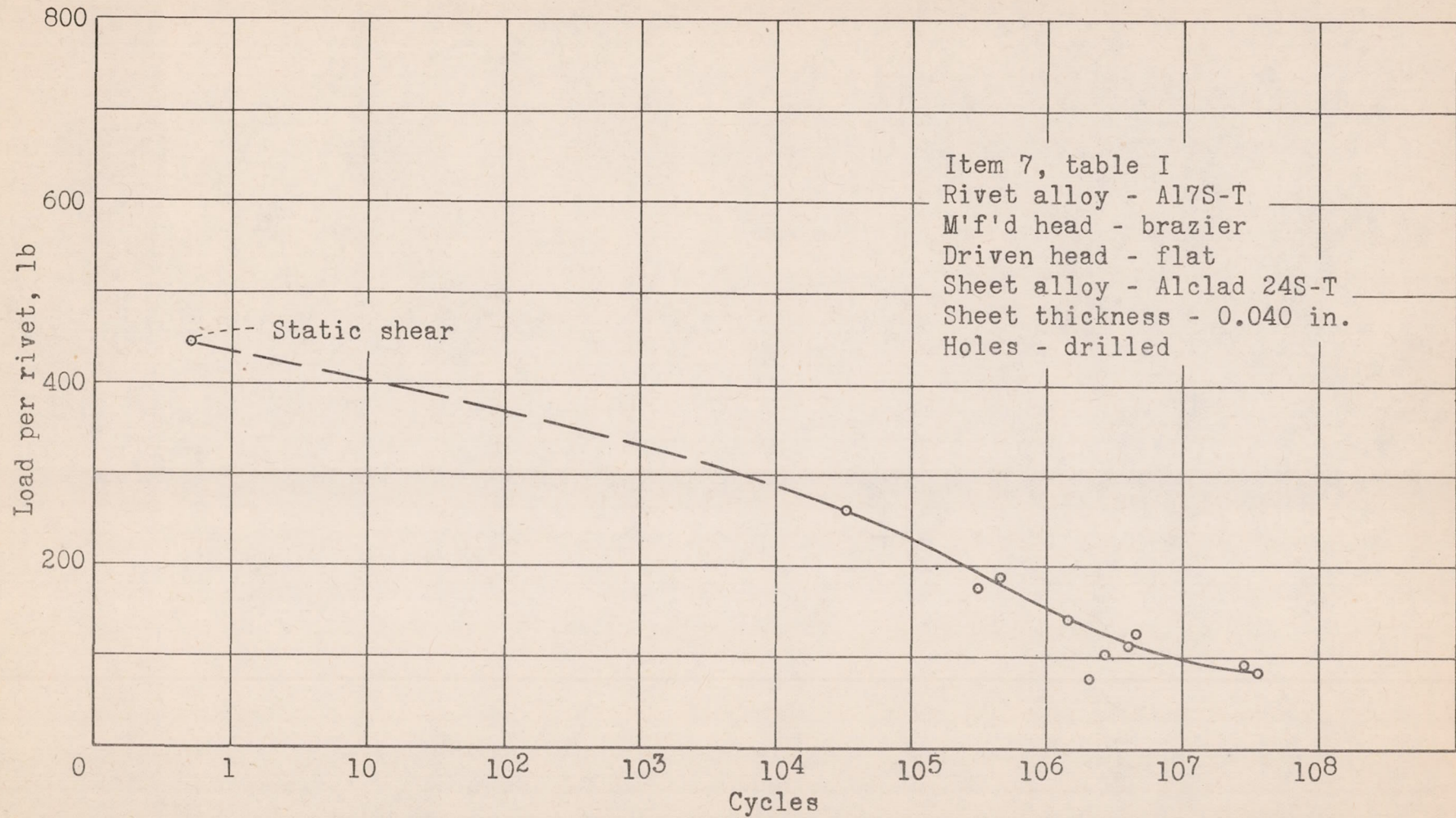


Figure 10.- Shear fatigue tests for 1/8-in. diameter aluminum alloy rivets.

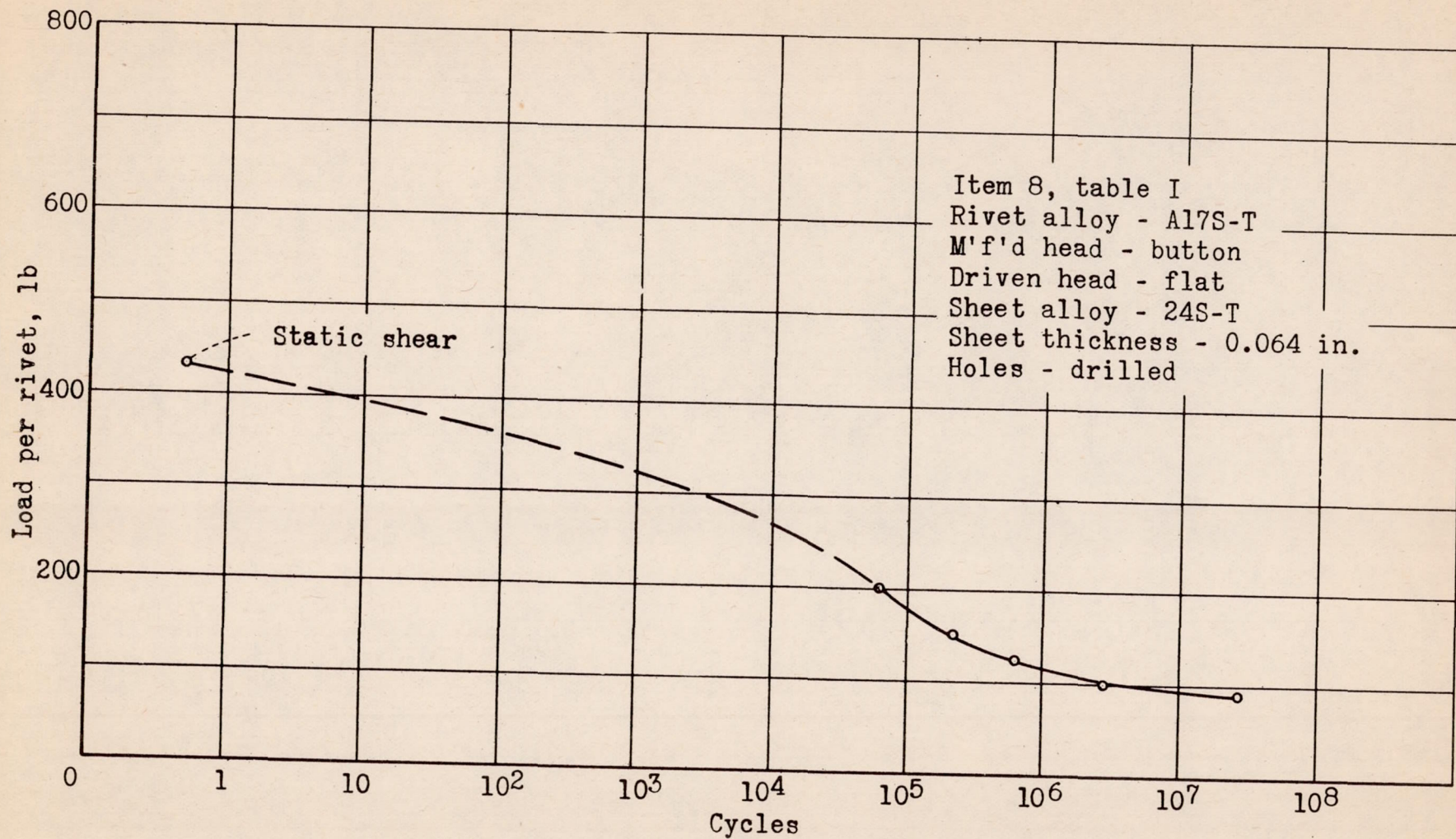


Figure 11.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

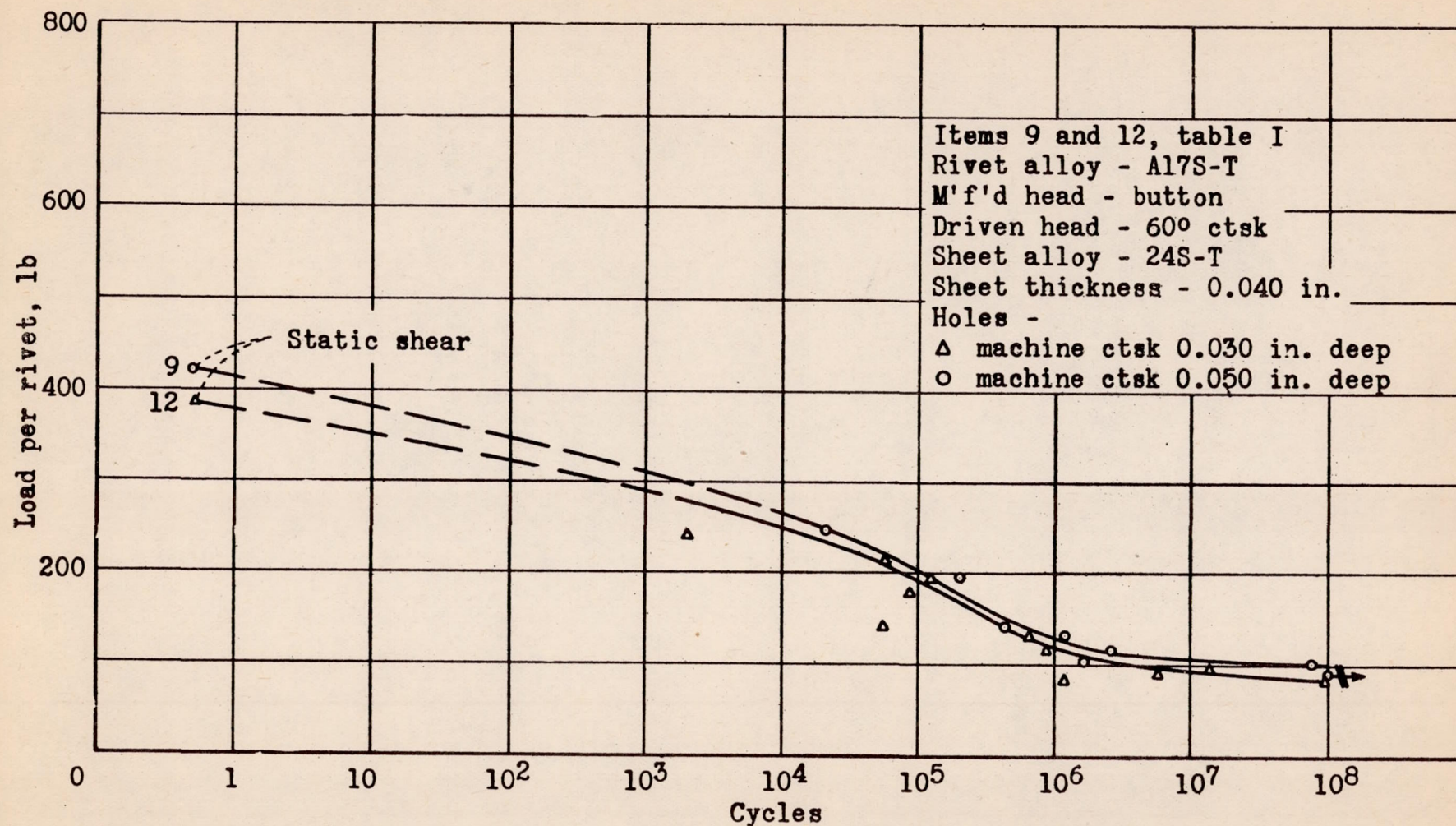


Figure 12.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

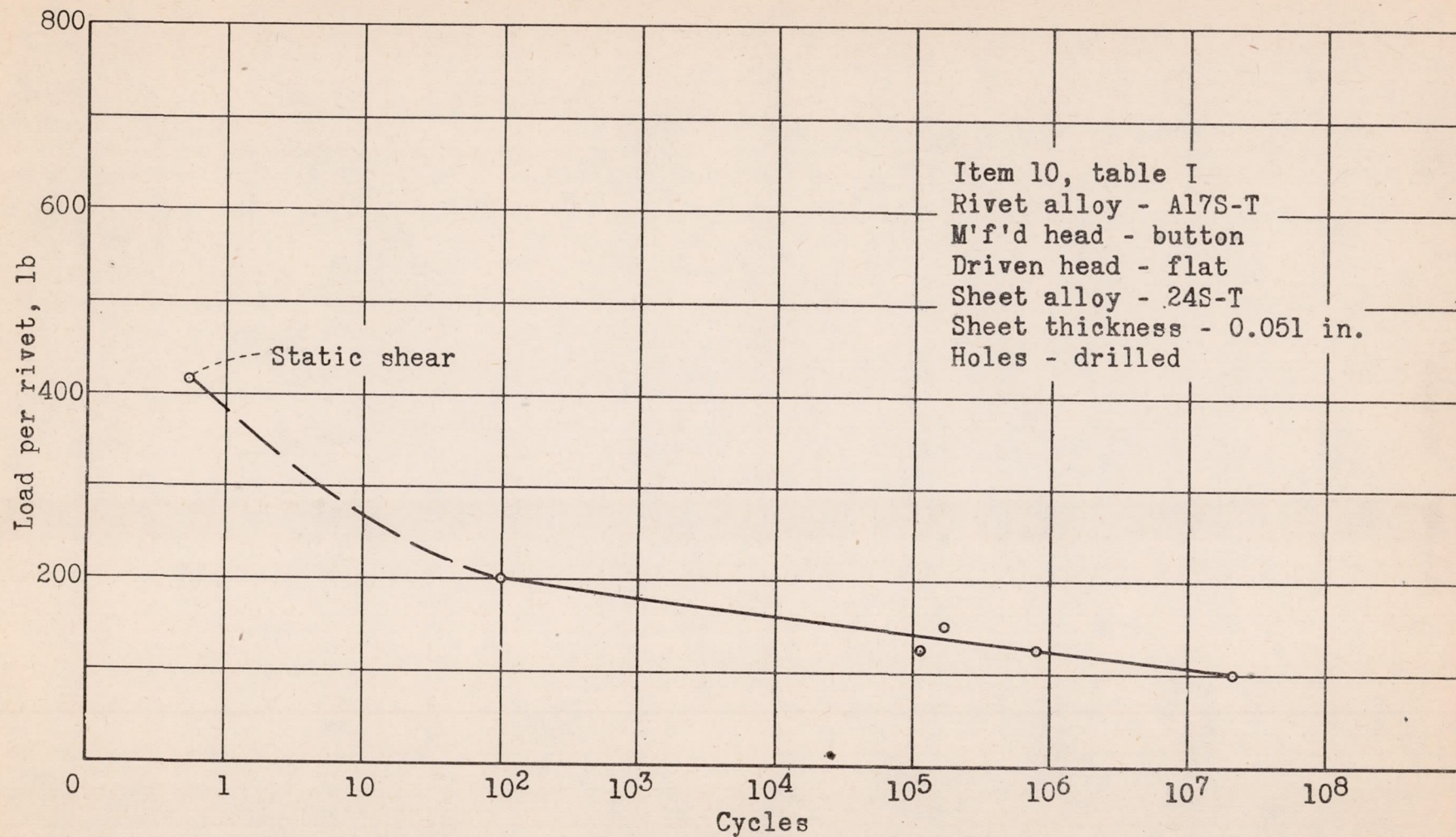


Figure 13.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.

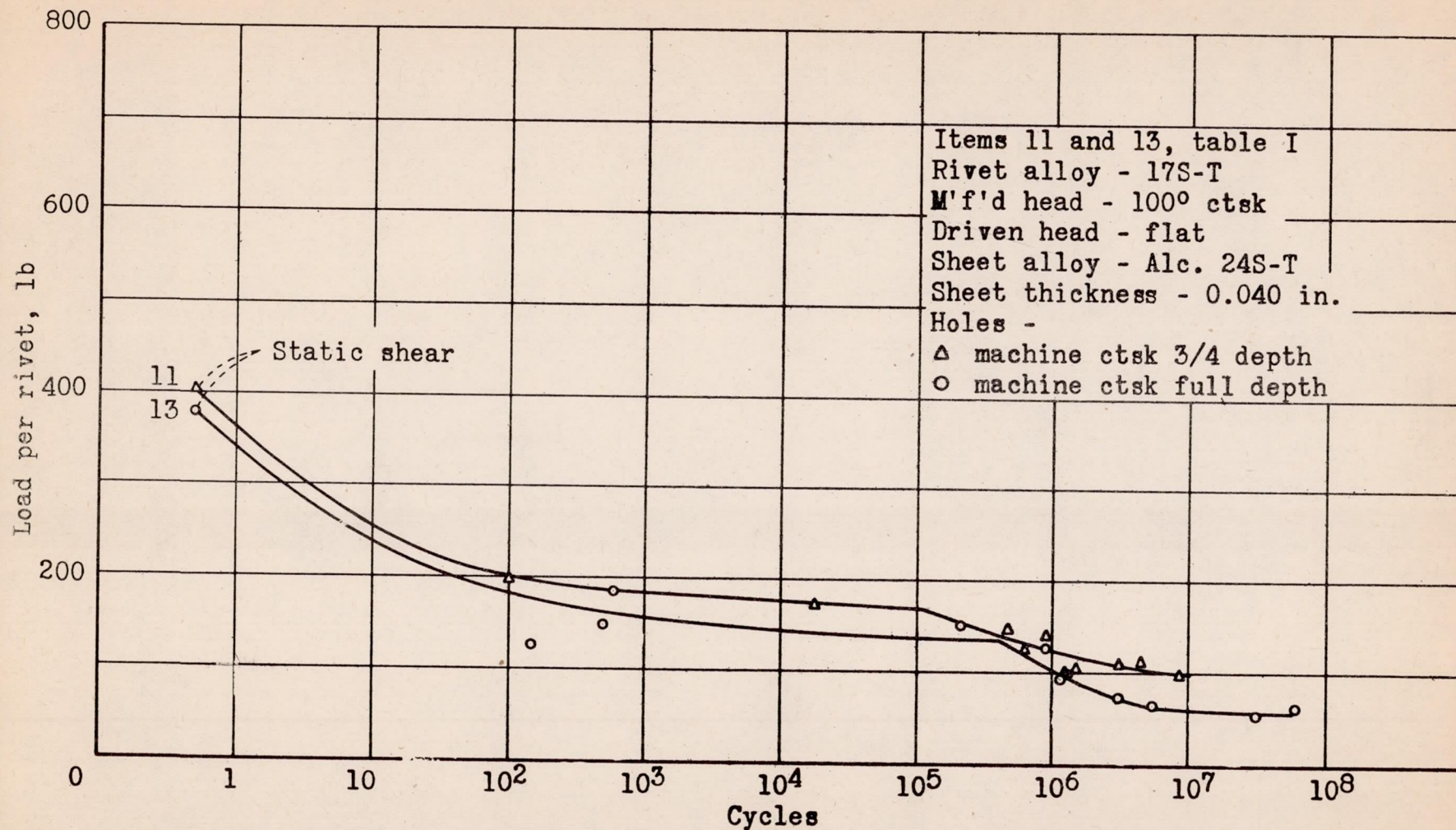


Figure 14.- Shear fatigue tests of 1/8-in. diameter aluminum alloy rivets.